Research on Design and Application of Power Dispatch Based on Blockchain

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ABSTRACT

With the large-scale access of renewable energy and the rapid development of electricity market operation, power dispatch urgently needs to improve the level of instant information sharing and service management capabilities. Through the blockchain technology, it can realize the credible sharing and traceability of key data, and further promote the efficiency of power dispatch collaboration management as well as the openness and transparency of the process of power dispatch. In this paper, the adaptability of blockchain and power dispatch business is analyzed, a power dispatch model with hierarchical management and hierarchical storage based on blockchain is proposed, and a fully functional dispatch blockchain platform is developed. Customized smart contracts are used to realize the automatic execution of the dispatch assessment and evaluation, and a consistency check mechanism is designed for the key data of the security and stability control device. Finally, two typical scenarios of dispatch management assessment and dispatch data management are selected for application research. The results show that the power dispatch model based on blockchain can significantly improve the transparency and operation efficiency of power dispatch, reduce the impact of the misoperation of the security and stability control device on the power grid, and promote the safe and stable operation of power grid.

CCS CONCEPTS

• **Computer systems organization** → Architectures; Distributed architectures; Peer-to-peer architectures.

KEYWORDS

Blockchain, Power Dispatch, Smart Contract, Dispatch Management Assessment, Dispatch Data Management

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1 INTRODUCTION

The power system is a huge and complex system. Many power plants produce electric energy and supply power to users through transmission, transformation, distribution, and power supply networks. The whole process of generation, supply, and sale of power are completed and balanced in an instant. Therefore, power production management must have an effective production command system to coordinate the power generation, supply, and use departments. This system is the power dispatch system. Generally speaking, power dispatch system mainly includes dispatch system at all levels and production and operation units at all levels. Production and operation units include power plant, substation, transmission line, distribution network, large user distribution system, etc. The main responsibility of the power dispatch organization is to implement unified dispatching and monitoring management for the power grid and power plants under its jurisdiction [1].

At present, with the operation of UHV AC/DC hybrid power grids, large-scale consumption of renewable energy, and rapid development of electricity market operations, the scale of power grids is rapidly expanding, and power dispatch structure is becoming increasingly complex, which puts forward higher requirements for integrated operation of large power grids [2]. In order to improve the real-time sharing level of dispatch information and service management level of dispatch applications, a lot of research have carried out in the aspects of network-wide information perception and synchronization, dispatch lean management, and in-depth data application. However, there are still many problems to be solved, such as the efficiency of multi-level management coordination needs to be improved, the demand for openness and transparency of the power dispatch process by market participants is increasing, and the credible sharing and traceability of key data in the dispatch process continue to increase. For the specific scenarios of power dispatch, in the power dispatch management assessment, although relevant assessment methods have been introduced, the subject to be assessed still hopes to further realize the openness, transparency and authenticity of the assessment process, enhance the credibility

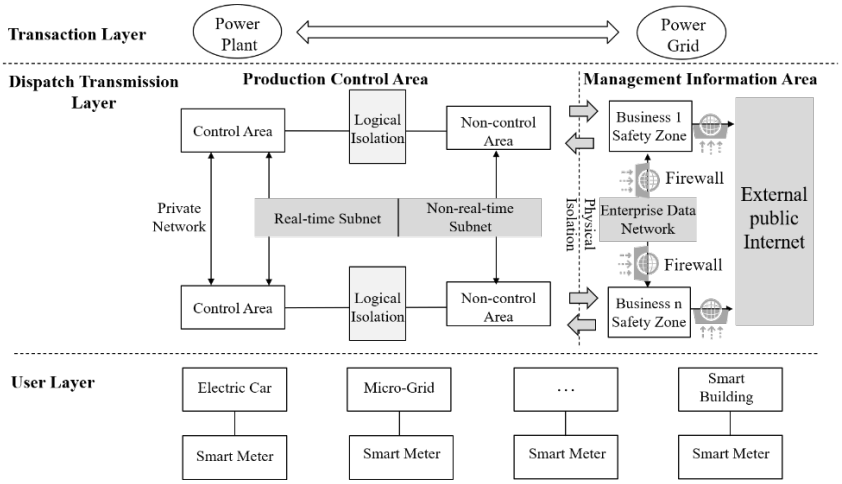

Figure 1: Power Dispatching and Control System Physical Architecture

of power dispatch assessment, and improve the efficiency of assessment. The security and stability control device is an important guarantee for the stable operation of the power grid. The key data in the operation of the security and stability control device needs to be consistent with the data verified by the laboratory. How to achieve efficient and reliable data consistency verification is also an urgent problem in the power dispatch process.

Blockchain technology has the advantages of distributed peer-to-peer, data blocks interrelated, tamper proof, transparent and reliable. It can promote the data sharing of related businesses, optimize business processes, reduce operating costs, improve collaborative efficiency, and build a trusted system. Its technical advantages are highly consistent with the digital transformation needs of the power grid. With the rise and development of blockchain technology, scholars gradually began to study the application of blockchain in power system, but most of the research focuses on distributed power trading, virtual power plant, microgrid, demand side response and integrated energy, and so on. Due to the complexity of the power grid backbone network, there is no mature blockchain-based power dispatch fusion scheme. In view of the problems faced by the power dispatch system due to the increasingly complex network, this paper deeply analyzes the advantages and characteristics of blockchain technology, and studies the adaptability and feasibility of power dispatch business integration blockchain technology. Firstly, for the typical hierarchical power dispatch cloud system, a power dispatch model based on blockchain is proposed, which breaks the data barrier between system levels, establishes the trust relationship between the main bodies of power dispatch business, and realizes the data sharing, tamper proof and traceability of power dispatch management process. Secondly, based on the power dispatch blockchain model, this paper proposes solutions for the two scenarios of dispatch management assessment and dispatch data management, creates an open and transparent dispatch assessment mode, and realizes the consistency verification of multi-party data at all levels of dispatch centers, plants and stations, as well as tamper proof and traceability of data in the flow process.

2 BACKGROUND

2.1 Power Dispatch System

The function architecture model of a typical power dispatch system mainly includes: transaction layer, dispatch transmission layer and user layer. 1) The transaction layer mainly includes various power plants and power grids in the power industry, and each entity can realize power transactions in this layer. 2) The dispatch transmission layer mainly includes the exclusive transmission channel of the power grid, that is, the dispatch transmission system composed of various levels of control agencies and various levels of substations. The dispatch system performs power dispatch and distribution according to the transaction agreement reached by the distribution transaction module at the upper level and its own regulation requirements. In this layer structure, the network implements private network isolation, and the transmission channel and the dispatching system do not interfere with each other to ensure the efficiency and safety of power dispatch and transmission. 3) The user layer mainly includes various types of consumers. A typical power dispatch system architecture is shown in Figure 1.

Based on the existing power dispatch system model, in order to continuously improve the real-time sharing level of dispatch information and the service management level of dispatch applications, and enhance data processing, data calculation and application sharing capabilities, cloud computing technology can be used to build a service platform with power dispatch as its core business – Power dispatch cloud. The power dispatch cloud adopts a hierarchical deployment method of dominant nodes + collaborative nodes to form a "1+N" overall architecture. Among them, the dominant node is at the core of the dispatch cloud, and the collaborative node is deployed in each regional dispatch center, focusing on regional local grid services.

2.2 Research and Application of Blockchain in the Field of Power

With the development and maturity of the power system, the power dispatch system needs to further improve the efficiency of the management programs and improve the accuracy and real-time of information monitoring. The increasing degree of digitization is an inevitable development trend of the power dispatch automation system. Blockchain technology is an open chain distributed ledger with a consensus algorithm, and a decentralized, transparent, and tamper-proof distributed accounting data structure [3]. Since the birth of blockchain technology, it has attracted widespread attention from all walks of life, and it has rapidly extended from the financial field to energy, logistics, government affairs, justice and other fields. Literature [4–8] and others have explored how to apply blockchain technology to the energy and power industry and promote the safe and stable operation of the power system. At present, blockchain is mainly used in distributed power transactions, electric vehicles, virtual power plants, and integrated energy. Literature [9–12] researched the distributed power transaction model based on blockchain. The literature [13–16] respectively proposed application solutions for electric vehicle charging transactions, charging pile key management, battery traceability and so on. In general, most of the exploration of blockchain technology is concentrated on the power generation side and the demand side. There are few blockchain application researches for the power backbone network dispatch system, and there is a lack of mature business models and perfect solutions.

Literature [17] aimed at the information security and loss problems in the process of integrated energy system dispatching, constructing a blockchain-based integrated energy service network architecture, and establishing a dispatch optimization model with the goal of maximizing system economic and environmental benefits, which can effectively improve the economic and environmental benefits of the system. Literature [18] is oriented to distributed microgrid transactions and power dispatch, by designing dynamic smart contract formulation methods and heuristic-based opportunistic task scheduling methods to achieve the goal of reducing users' economic expenses and increasing revenue. Literature [19] studied the distributed dispatch strategy of virtual power plants, and proposed using the blockchain consensus mechanism to realize distributed dispatch of virtual power plants, combined with the equal consumption micro-increasing rate criterion, and using micro-increment characteristics as consistency variables. So as to realize the optimal economic dispatch of the virtual power plant. It can be seen that the blockchain-based dispatch application scenarios are more biased towards limited-range scenarios such as integrated energy, microgrids, and virtual power plants.

3 BLOCKCHAIN-BASED POWER DISPATCH ARCHITECTURE

3.1 The Adaptability of Blockchain and Power Dispatch

The power dispatch business is gradually developing in the direction of openness, reciprocity, interconnection, and sharing, and the technical characteristics of the blockchain exactly fit the reform direction of power dispatch. The technical architecture of the blockchain enables it to have the characteristics of distributed storage, data synchronization, partition consensus, tamper-proof, traceability, multi-agent mutual trust and recognition, and gives smart contracts new vitality. These characteristics of blockchain technology are naturally compatible with the needs of new power dispatch of preparation mechanisms, unified dispatch, hierarchical management, dispatch traceability, responsibilities clear, rule assessment, and automatic assessment. Blockchain technology has broad application prospects in the field of power dispatch shown in Figure 2.

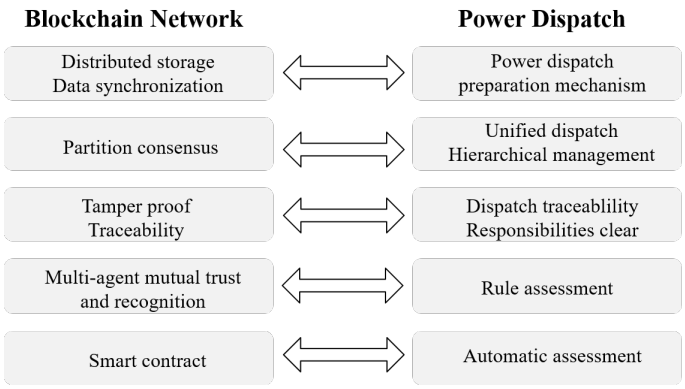

Figure 2: Integration Function Points of Power Dispatch System and Blockchain

3.2 Blockchain-based Power Dispatch Model

In blockchain networks, participating nodes are usually divided into full nodes and light nodes based on the difference in computing power. Full nodes contain complete blockchain data and support the functions of all blockchain nodes; light nodes are that rely on full nodes and do not need to provide computing power for the blockchain network, and only need to retain part of the blockchain data. Blockchain and power dispatch cloud architecture have similar network topologies. From the perspective of the technical integration of blockchain and power dispatch, the blockchain architecture and nodes can be mapped to the hierarchical structure model and key function nodes of the power dispatch cloud, and a blockchain-based power dispatch model with the characteristics of "hierarchical management and hierarchical storage" can be constructed, shown in Figure 3.

According to the computing power, dispatch characteristics and data importance of various types of nodes in the power dispatch system, the power dispatch cloud nodes can be classified as follows: 1) The energy and power end node is positioned as a full node, this type of node has the strongest computing and storage capabilities, with complete functions such as billing, settlement, saving complete blocks, query, and verification, including dominant nodes and regional-level collaborative nodes; 2) Other nodes at all levels in the energy and power transmission network and nodes at all levels of substations are positioned as light nodes. This type of node has very limited computing power output and insufficient storage space

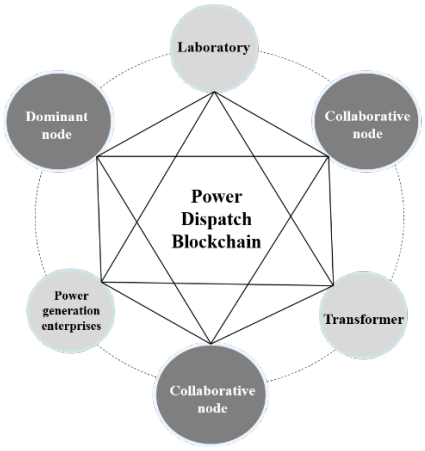

Figure 3: Blockchain-based power dispatch model

to retain the complete blockchain, so it only has basic functions such as storing blocks within a few months, routing, querying, and verifying.

In the deployment of the power dispatch blockchain network, the power dispatch center acts as a super node, and each sub-center participates in the consensus of the blockchain as a consensus node, and other dispatch agencies at all levels and their affiliated power plants and substations act as light nodes and do not participate in the consensus. The whole model guarantees the high efficiency, rationality and orderliness of data sharing under the premise of ensuring the credible sharing of power dispatch network data.

3.3 The Power Dispatch Blockchain Platform Architecture

The blockchain-based power dispatch model has great reference significance for ensuring the authenticity and traceability of grid data circulation, promoting the establishment of a transparent and credible dispatch management system, effectively breaking through information barriers, and realizing the value of data. On the basis of the power dispatch cloud platform, blockchain technology can be used to construct a public dispatch blockchain service platform. Its overall architecture is shown in Figure 4. The platform anchors key data information in dispatch management on the blockchain, and effectively solves the security problem of key data storage by setting different users' access rights to key data.

4 TYPICAL APPLICATION OF BLOCKCHAIN IN POWER DISPATCH

Power Dispatch is involved in many aspects of the operation and management of power production. Combined with the advantages and characteristics, the blockchain technology shows a good application value in the aspects of dispatch management assessment and data management. Relying on the power dispatch model using blockchain technology, this paper proposes solutions for the two scenarios of power dispatch management assessment and data management, and has been put into operation in a pilot application in China. The results shows that the solutions effectively reduce the misoperation and disputes, improve the operation efficiency and the security and stability of the power production.

4.1 Solution

4.1.1 Dispatch Management Assessment. In order to standardize the grid-connected operation management of power generation companies and reasonably evaluate the quality of their auxiliary services, the energy regulatory agency will formulate grid operation management specifications and conduct assessments on power plants and other relevant entities to promote safe and stable operation of the power grid. However, in the current environment of the electricity market, how to ensure that market entities quickly acquire the information of the whole process of dispatch management assessment and improve the transparency and credibility of dispatch management assessment is an urgent problem to be solved. The application of blockchain technology can realize the entire assessment process on the blockchain, and realize the authenticity transparency, and open sharing of the assessment process. Details in the following aspects:

- Put the data to be assessed from the power plants on the blockchain for certification to realize the tamper-proof and traceability of the data;
- Using smart contract technology to automatically trigger execution and save the results on the blockchain. The assessment results cannot be tampered with, which improves the efficiency and transparency of the assessment;
- After the assessment data and assessment results are put on the blockchain for certification, each node of the blockchain will save the same data, and the data can be shared among market entities.

The logical architecture of the blockchain-based dispatch management assessment system is mainly divided into four parts: the collection layer, the storage layer, the logic layer, and the application layer. The architecture is shown in Figure 5.

The collection layer mainly includes intelligent terminals such as synchro phasor devices, measurement and control devices, protection device, edge agent devices, etc., to realize the collection and preprocessing of basic data required for the assessment and management of power plants. The above-mentioned intelligent terminal can realize the collection and processing of data such as steady-state, dynamic, transient, thermal power unit comprehensive monitoring, renewable energy comprehensive monitoring, and online monitoring of power transmission and transformation equipment. The dispatch center and the power plant jointly maintain the smart terminal to ensure that the data is accurate and correctly to be stored on the blockchain. The data collected by the collection layer is directly stored on the blockchain to ensure that the blockchain collects original, true and credible data from the power plant side, providing a reliable basis for the assessment.

The storage layer mainly includes the dispatch blockchain platform, which stores the data collected by the collection devices of the collection layer. After cleaning, the hash value of the electronic file is stored in the block to support power dispatch assessment. The data is organized and stored in the form of chain, and the energy regulatory agency and multiple power plants other than the assessed power plants reach an agreement through a consensus

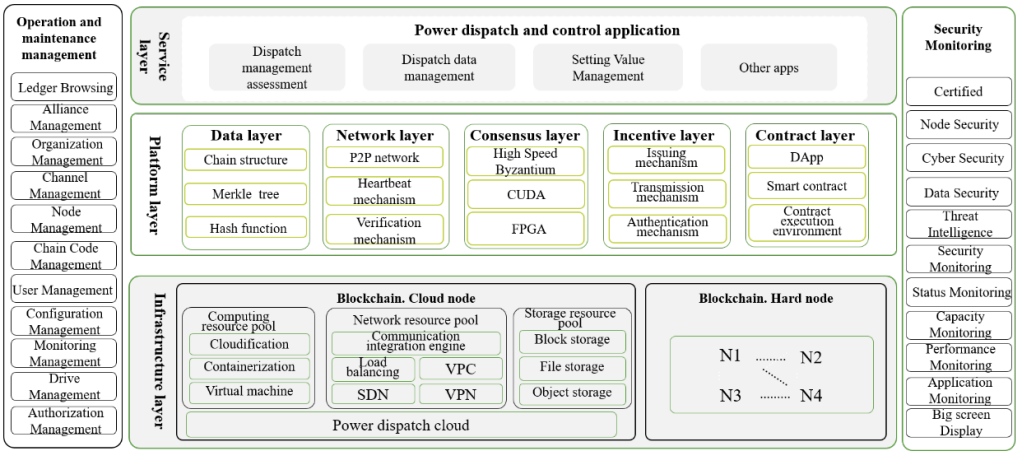

Figure 4: Overall Architecture of Power Dispatch Blockchain System

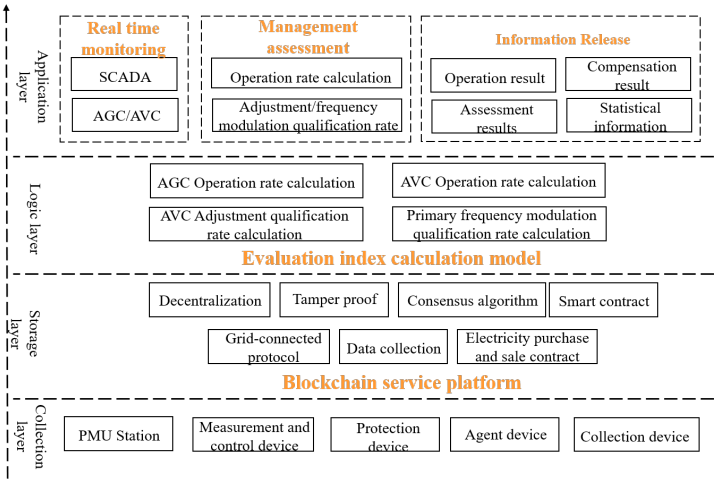

Figure 5: Logical architecture of dispatch management assessment based on blockchain

mechanism. It should be noted that, based on data security and user information confidentiality, hierarchical authority control is performed on storage data access users.

The logic layer realizes assessment index calculation, data verification and data analysis by constructing automatic power generation control (AGC) operation rate calculation model, automatic voltage control (AVC) operation rate calculation model, AVC adjustment qualification rate calculation model and primary frequency modulation qualification rate model, etc. Use the customized smart contract of the blockchain to solidify all the assessment models of the assessment rules to the blockchain platform, automatically execute the dispatch assessment, and calculate the assessment results. This mechanism can achieve credible power dispatch assessment and evaluation without the participation of a third party. The evaluation results are traceable and irreversible. In the process of executing the smart contract, the pre-set code on the distributed node can be used to enforce the smart contract and ensure that the smart contract cannot be interfered.

The application layer mainly supports the implementation of dispatch assessment services, and realizes various functions in the functional modules, including real-time monitoring of power dispatch, management assessment, and information release. The application layer serves as the window used by the blockchain to facilitate users to query real and reliable block data and assessment data in real time to meet the needs of assessment and evaluation on the power generation side and the dispatch side.

4.1.2 Dispatch Data Management. With the development of power systems, security and stability control systems and devices as the second line of defense to ensure the safe and stable operation of the power grid have been widely used, but it also makes the maintenance and management of security and stability control devices very complicated. Although various dispatch centers have successively built security control management systems to implement centralized monitoring and management of security and stability control devices, the devices scattered in various places still face many difficult-to-control risks. On the one hand, the accuracy and

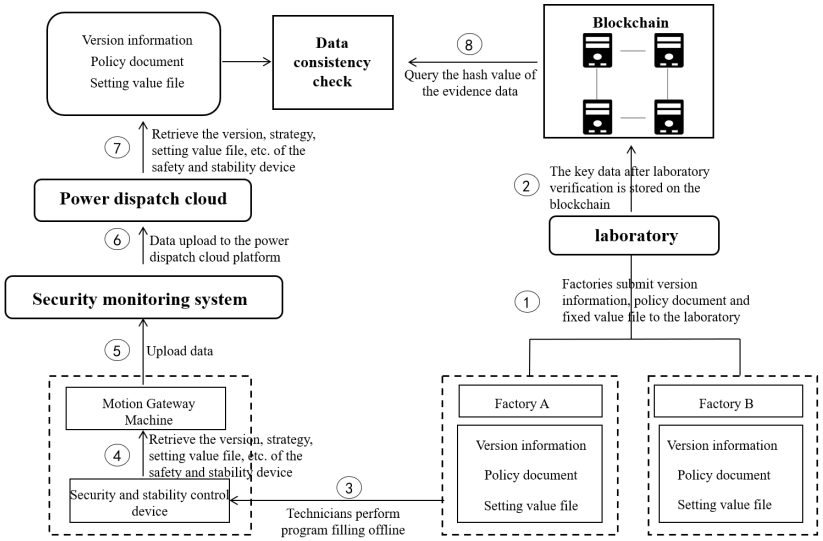

Figure 6: Security and stability control device management based on blockchain

safety of data such as the software version, execution strategy, and setting value of the devices operating in the plant needs to be guaranteed to prevent malicious tampering and deletion, and real-time monitoring and dispatch inspection of operating data and laboratory verification data are required consistency. On the other hand, the control model is constantly updated and upgraded with the changes in the practical production environment, and the version update history has important reference value for the control business. Based on blockchain technology, it is possible to carry out credible storage of important operating data of security and stability control devices on the blockchain, realize the development of consistency verification of the device data, and provide historical model data for control applications according to application requirements.

- Security and Stability Control Device Management

The security and stability control device manufacturer first submits the safety control software version, safety control execution strategy and setting value to the system protection laboratory for test and verification. After the verification is passed, the laboratory uploads hash value of the software version, execution strategy and setting value to the Power Dispatch Blockchain for on-chain certification, and all levels of regulatory agencies, system protection laboratories, and manufacturers on the blockchain will jointly witness and endorse the accuracy of the data on the chain. On the plant site, each manufacturer fills the programs such as version information, strategy files, and setting value files verified by the laboratory offline and deploys them to the security and stability control device. In the production and operation process, the motion gateway device regularly retrieves the data version, strategy, setting value file and other information of the substation safety control device according to a certain time period and uploads it to the master station. After receiving the relevant data, the security monitoring system transmits the security and stability control device data to the Power Dispatch Cloud (PDC) platform through the isolation device. Retrieve the relevant data of the PDC platform and calculate the data fingerprint, and compare it with the stored information on the Power Dispatch Blockchain. It is able to be judged whether the program filled by the manufacturer in the security control device is in line with the one tested and verified by the lab. Once inconsistencies occur, the PDC platform will automatically generate alarm messages to reduce the risk of tampering or misoperation of security and stability control device data, and to ensure the standardization of business and the security of the data. The whole process of the security and stability control device data consistency verification is shown in Figure 6.

- Model Data Management

As the production environment of the power grid continues to change, the PDC model data is constantly updated. The historical data of the dispatch model plays a very important role. On the one hand, the historical dispatch model records important information such as the version, time, area, equipment, and voltage level of the previous model. This information has important reference value for the upgrade and development of the dispatch business. On the other hand, when a major production liability accident occurs, the cause of the accident can be located and the responsibility of the accident can be traced by analyzing the previous dispatch model. This shows that it is necessary to build credible records for the historical dispatch model. Based on the blockchain technology, the data version of the dispatch model can be effectively managed. When the model changes, the smart contract will be automatically triggered to store the current model to the blockchain. The relevant parties can apply to the blockchain system to query the historical dispatch model according to the application requirements and time, region, equipment, voltage level and other conditions. The use of blockchain technology can ensure the model to be stored on the blockchain automatically and credibly, reduce manual operation costs, improve business efficiency, and ensure the tamper-proof and traceability of the model data. Figure 7 shows the data management process of the dispatch model based on blockchain.

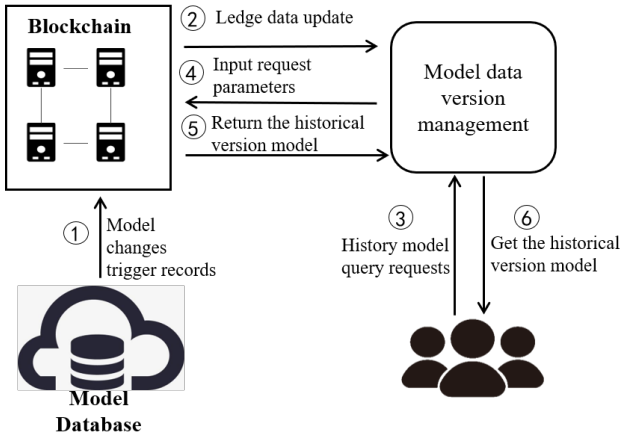

Figure 7: Power dispatch model data management based on blockchain

4.2 Application Effectiveness

During the construction of a key power dispatch project in a province of China, the pilot application of the blockchain based dispatch management assessment mechanism and dispatch data management mechanism was carried out. In order to standardize the grid operation and management of power plants and reasonably evaluate the quality of their auxiliary services, the regulatory agency has formulated and issued two documents: Implementation Rules for grid operation and management of regional power plants and Implementation Rules for auxiliary services management of regional power plants. In the pilot application of transparent dispatch based on blockchain, the specific assessment rules of the two files are written in the smart contract. At the collection end, the relevant information of PMU substations, measurement and control devices, relay protection devices, fault recorder collection devices, etc. are collected through intelligent collection equipment and stored on the blockchain platform. Then, based on the assessment logic implemented by the smart contract, the calculation of the assessment indicators such as the AGC operation rate, AVC operation rate, AVC adjustment qualification rate and primary frequency modulation qualification rate is automatically carried out. Relevant parties of dispatch assessment can conveniently view assessment results, operation results, compensation results, grid operation statistics, etc. The implementation of the project greatly improves the enthusiasm of power plants, enhances the self-discipline consciousness of power grid enterprises, and enhances the credibility of power dispatch work. After the implementation of the project, the number of disputes about dispatch management assessment has been reduced by 80%.

In the pilot application of dispatch data management based on blockchain, the project selects three 220kV substations in a certain area as the pilot units, and the relevant manufacturers, system protection laboratories and dispatch agencies at all levels in the area are connected to the completed power dispatch blockchain network. During the operation of the project, the security and stability control devices in the substation are selected as the experimental objects to monitor and verify the consistency of the model version, implementation strategy and important setting data of these devices in real time. The results show that after using the blockchain technology to monitor the consistency of the key data of the security and stability control device in real time, the data inconsistency caused by misoperation can be found in time and the alarm will be given automatically. During the operation of the project, there were nearly ten data filling errors of security and stability control devices, which were found and alarmed in time without causing significant production losses.

5 CONCLUSION

Power dispatch system integrates data acquisition, storage, analysis and decision-making of power grid, and runs through all links of power system, such as generation, transmission, transformation, distribution and utilization. It is the control center to ensure the safe, stable and economic operation of power grid. In order to further promote the collaborative management among all levels of the power dispatch system, realize the trusted sharing of data, and build an open, transparent and efficient dispatch management system, this paper proposes a widely interconnected power dispatch system model with hierarchical management and storage features based on blockchain technology. In this model, different levels of dispatch agencies play their respective roles, jointly promote the realization of data sharing based on authority management, and ensure the security of information flow. In the specific scenario of power dispatch, in order to ensure the transparency of dispatch management assessment process of power plants and enhance the credibility of assessment, a transparent dispatch assessment mechanism based on blockchain is proposed. In addition, a dispatch data management mode is designed by using blockchain technology, which provides technical support for the smooth operation of the security and stability control device. These two schemes have been applied in practical projects, and the results show that blockchain technology has high application value in the power dispatch. In the future, we will be deeply engaged in the power dispatch, and further explore the integration of blockchain and more power dispatch business scenarios, so as to promote the continuous improvement of the digital level of the power industry.

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